भारतीय मानक

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Indian Standard

फ्यूनिकुलर रेलवे का डिज़ाइन और निर्माण — रीति संहिता

Design and Construction of Funicular Railway— Code of Practice

ICS 93.100

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भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

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Continuous Bulk Conveying, Elevating, Hoisting Aerial Ropeways and Related Equipment Sectional
Committee, MED 6

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Continuous Bulk Conveying, Elevating, Hoisting, Aerial Ropeways and Related Equipment Sectional Committee had been approved by the Mechanical Engineering Division Council.

This standard proposes to cover Funicular Railways for which no applicable standard is available.

A funicular is a grade-separated fixed guideway transit system powered by a cable traction designed for steep inclines. A funicular uses two counterbalanced passenger cars attached to the opposite ends of a cable, which is looped over a pulley at the upper end of the track

Funicular Railways are also useful in regions where the facility in surmounting natural barriers gives them a great advantage over conventional railways or roads, both of which may need the heavy civil engineering work to secure easy gradient. They are inexpensive to maintain, pollution free, environment friendly, does not affect aesthetics, their power demand is modest. Nothing in this standard is intended to contravene any provisions of the statutory regulations wherever they are in force.

The composition of the committee responsible for the formulation of this standard is given in Annex B.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values’ (*second revision*). The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

DESIGN AND CONSTRUCTION OF FUNICULAR RAILWAY — CODE OF PRACTICE

1 SCOPE

This standard covers the design and construction of Funicular railways meant for the transportation of passengers and goods in separate cabins.

2 REFERENCES

The Indian Standards listed in Annex 'A' contain provisions which through reference in the text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 TERMINOLOGY

For the purpose of this standard, the following definitions in addition to those given in IS 7649 shall apply.

3.1 Funicular Railway

The term funicular derives from the Latin word '*funiculus'*, the diminutive of '*funis'*, meaning *'rope'*.

Funicular Railway is a special form of transportation system and falls under 'Ropeway' family where vehicles (cars) of Funicular railways run on a track which is laid on the ground or on rigid structure. Vehicles are propelled by means of traction ropes which are used to transmit the drive power and moves on wheel with simultaneous ascending and descending of cars counterbalancing one another. This is particularly useful where large no of passenger transportation is required and is generally not affected by adverse climatic conditions.

3.1.1 In this type of system, vehicles running along rails at ground level and drawn by a rope at one or both ends, together with any machinery, equipment or plant connected therein.

3.1.2 Here single or cluster of cabins are placed together with the rope and is placed on diametrically opposite sides where the system moves from one station to another with a particular direction and on completion of the journey it reverses its direction of movement and the same cycle continues.

3.2 LINE is defined as a route alignment of the railway between two terminals.

3.3 Inspecting Authority

Competent authority recognized by the statutory regulations to inspect the aerial ropeways installation and determine its acceptability or otherwise, on the basis of this Standard and compliance to prevailing statutory rules and regulations.

4 GENERAL REQUIREMENTS

4.1 Guidelines for Design and Construction

4.1.1 Each part of the ropeway equipment shall be designed and constructed in conformity with this Standard. The quality of the materials to be used for its construction shall be as per the design. A certificate of doing so shall be given by the constructor to the purchaser & will be kept till the life of the product.

4.1.2 On the request of the supervising authorities or the purchaser, the constructor shall supply a certificate of a recognized (NABL/ statutory accredited) testing lab as regard to characteristic of material used and essential to the safety of the installation.

4.2 Layout

4.2.1 A Funicular railway shall be routed so that its effect on the environment is minimal; this involves consideration of noise pollution, unsightly construction and any detrimental visual impact on the local environment. In the design of the routing of a railway, due regard shall be given to existing hazards such as vegetation, roads, bridges, electric power lines, streams, buildings and slope stability.

4.2.2 When establishing the course of the line of funicular railways, the following shall be taken into account:

a) The transverse acceleration acting on the passengers;
b) The safe support of the rope on the rollers;
c) The safe guidance of the carriages on the track, also taking into account
d) Any possible load reduction on the wheels;

e) The necessary braking force and the safe functioning of the track brake; and
f) The characteristics of the carriers.

4.2.3 The transverse acceleration shall not normally exceed 0.65 m/s^2. It may increase to 1.0 m/s^2 if a transition curve restricts the jerk to maximum 0.8 m/s^3. Superelevation of the track to limit the transverse acceleration is permissible.

4.2.3.1 Neither superelevation nor the radii selected for curves shall adversely affect the safe guidance of the carriages and the effectiveness of the track brakes.

4.2.4 For reasons of safety and comfort during the journey, the gradient of the track shall be selected so that the actual longitudinal inclination of the carrier floor varies at most by ± 0.20 radians to the horizontal. In case the ground shape does not permit this then a mechanism in the carriage should be provided to compensate for the same.

4.2.5 The length of the passing loop shall be established so that when the track brakes are induced as a result of a ruptured haul rope or if the rope end fixings fail, there is no collision between the carriers.

4.2.6 When the track brakes are triggered on descending carriers, the following shall be taken into account:

a) Most unfavorable carrier positions;
b) Reaction time of the on-board brake on descending carriers with subsequent stopping distances;
c) Drive stopping distances, coasting of ascending carriers; and
d) Downhill force of the counter rope.

When the track brakes are triggered on ascending carriers, the following shall be taken into account:

a) Most unfavorable carrier positions;
b) Position of the ascending carrier after own deceleration and application of the on-board brake after reverse travel direction;
c) Position of the descending carrier after application of the on-board brake as a result of over-speed with subsequent stopping distances; and
d) Downhill force of the counter rope.

4.3 Profile Limitation

4.3.1 A longitudinal profile (normally at a scale of 1 : 500 or 1 : 1000) with an indication of the terrain, the position and altitude of the line structures, bridges, retaining walls and stopping points. The longitudinal profile shall also include – as simple lines with names – all crossing points with railway lines, roads, paths and other transport routes, watercourses, electricity lines and oil, gas and water pipelines.

4.3.2 Cross-sections, in particular for the zones where carriers meet and for the zones where clearances of the carriers are restricted laterally in the stations by buildings, rocks, etc. (for example at a scale of 1 : 50 or 1 : 100).

4.3.3 The following shall be taken into account:

a) Movement of the carrier in the horizontal and vertical planes when travelling round curves in the track;
b) The lateral play of the carrier;
c) The possible movement of the carrier on its suspension in all directions;
d) The lateral movement of the wheels relative to the rails;
e) The possible dimensional tolerances (e.g. On the carrier, on the position of the rails);
f) The hand area is 1.0 m for all window openings and for open carriages. Where a window does not open more than 0.2 m, the hand area is:
    i) 0.2 m, where the lower edge of the open window is at least 1.8 m above the floor of the carrier,
    ii) 0.5 m, where the lower edge of the open window is 1.5 m to 1.8 m above the floor of the carrier.

4.4 Safety Distances Required for Funicular Railways

4.4.1 A minimum safety distance of at least 0.3 m shall be provided between the limit profiles of carriers of a funicular railway as well as between the limit profile of a carrier above and to the side of any fixed structure or civil engineering. With the exception of parts of the installation which shall be arranged more closely for functional reasons (for example, track, platform and proximity switch equipment).

4.4.2 Passageways for operating personnel along the line shall be located outside of the limit profile according to 4.3, whereby the hand area does not have to be taken into consideration. The passageways shall be at least 0.6 m wide and have a minimum clear height of 2.0 m.

4.4.3 In specific cases (for example in tunnels and on bridges), passageways for servicing work when the installation is not in operation shall be provided on either side of the limit profile; the minimum width on one side may be reduced to 0.3 m.

4.5 Winds, Rainfall and Other Characteristics

4.5.1 In the calculation of wind action on the cables, the surface area to be considered shall be the diametric surface of the cable multiplied by the factor (C_w) given below:

$C_w \approx 1.1$ for snow bound areas

$C_w \approx 0.7$ for areas not affected by snow

4.5.2 Sometimes these Funiculars are subjected to the severe winds and rainfall. For that reason, the design of any exposed equipment and the selection of any materials used in the construction shall give due regard to the said factors. Wind may act in any direction, including upward direction. As a general rule the pressure of the wind Pw (N/m^2) on tramway and all exposed equipment may be calculated by the following empirical formula:

$$P_w = V_w^2/1.6 \text{ N/m}^2$$

where V_w is the maximum expected wind velocity in m/s in the vicinity of the line.

4.5.3 The above empirical formula may be adjusted proportionately by any variation in temperature or density of the air from the nominal condition of 15°C and 1.25 kg/m^3. However, even without any adjustment, this value is considered appropriate as a first approximation. The vehicle shall be designed to sustain a minimum wind load of 250 N/m^2 in operation.

4.5.4 Further, loads due to snow in accordance with IS 875 (Part 4) shall also be considered. In addition, other special loads in accordance with IS 875 (Part 5) shall also be considered while designing the funicular.

The ropeway design shall also consider seismic loads in accordance with IS 1893.

4.5.5 It is necessary to ensure that on a Funicular railway the rope will be required to keep its normal position by the rope guidance devices and supports under any condition of operational speed or load and, in addition, under the influence of any external factor such as wind effects.

4.5.6 The sheave guides etc., shall be designed to accommodate any side thrusts, if applicable.

4.5.7 When there are crossings with other communication paths or with overhead electric lines, a minimum clearance shall be maintained in order to take into account the requirements of the Indian regulation for clearance from roadways, powerlines etc.

4.6 Operating Speed

4.6.1 The operating speed of a system shall be designed taking into account but not limited to:

a) The safe and steady operation of the vehicle;
b) The operational capability of the braking systems;
c) The condition of the track;
d) Static and dynamic forces on the vehicle; and
e) Comfort of the ride and passengers.

4.6.2 Maximum operating speeds of up to 5m/s are permitted, provided that:

a) All effects of the higher speed have been taken into account;
b) The track is as reasonably practicable not accessible to the general public;
c) The operating speed is continuously adjustable over the whole length of travel;
d) The whole track, except for cross-over, is straight or the radius of any curve (in m) is at least 6 x v2 where v is the operating speed in m/s; and
e) The vehicle is equipped with suitable type of suspension.

4.6.3 The maximum operating speed may be exceeded under test conditions, without passengers, for the purpose of inspecting the over-speed safety devices. The test shall be carried out by competent and responsible staff and under no circumstances the carrying out of the test should prejudice safety.

4.6.4 In case of system speeds above 3 m/sec, the haul rope should be electrically monitored and the vehicle shall be brought to stop by a monitoring circuit when it comes in contact with roller support structures or external flanges of the support rollers.

4.6.5 When the vehicle is powered by emergency supply (not rated for 100 % demand load), the operating speed shall be suitably reduced to prevent overloading the emergency supply system. The emergency supply must be, however, able to drive the vehicles to reach either terminal station from any location within one hour. Emergency supply system may be an emergency generator.

4.7 Vehicle

4.7.1 The calculation of the various components shall be done, taking into account the weight of 75 kg per passenger.

4.7.2 The finite element analysis method shall be used to calculate and verify the design calculation of the structure and load bearing components of the vehicle which shall take into account all anticipated static and dynamic forces that will be encountered in operation including:

a) Vehicle own weight plus payload;
b) Wind effect during operation;
c) Impact force due to passenger loading and unloading;
d) Braking force of service and emergency brake;
e) Vehicle colliding buffers; and
f) Rail braking forces.

4.7.3 All components of the structure of the vehicle shall be easily accessible for inspection and maintenance. All internal and external surfaces shall be protected against corrosion.

4.7.4 The enclosure of the vehicle shall have the following provisions to ensure maximum safety to the passengers:

a) Vehicle shall be provided with body panel up to 0.4 m above the seating surface or 1.1 m above the floor surface for cabin with standing passengers. Sharp edges and abrupt protrusion inside the vehicle and near the door openings shall be avoided. Body panel material may be metal or fiber glass.
b) Enclosed vehicles shall be adequately ventilated by means of operable windows or mechanical ventilators. Windows shall be of non-splintering materials e.g. safety glass or synthetic plastic material;
c) Doors shall be so secured that they can be opened only by a purposed action. For power operated doors, the closing force shall not exceed 150 N. The edges of the doors shall be buffered with a soft material. In case of power failure, the doors shall be kept locked and shall be capable of being opened by hand from both inside or outside of the vehicle with the aid of a key. Keys of this type shall be kept only by responsible persons;
d) For vehicles which are unattended, all door opening mechanisms should be operated from the outside and shall not be able to be opened from inside;
e) Folding doors shall be opened only into the vehicle. Doors which open outwards shall be secured by locking devices and can only be opened from the outside;
f) The Funicular shall not be operated for carrying passengers with the vehicle doors in the opening position;
g) An emergency exit door, not on the same side as the normal exit door, shall be provided to give an adequate means of exit from the vehicle direct to the track in case of vehicle/system breakdown. This is applicable where entry and exit to the cabin is provided from one side only. This is not required for cabins that have doors on either side of the cabin for entry and exit respectively.
h) In case of cabins that require the presence of an attendant in the cabin as per requirements in other Indian Standards then a separate compartment should be provided for the attendant. The attendant’s cabin should be on the uphill side of the cabin and this would be sufficient if the attendant still has a clear line of sight towards the downhill side of the track. In case such line of sight is not there then a separate compartment at both ends of the vehicle shall be provided for the attendant. Alternatively a CCTV arrangement may be provided to give him a clear view of the downhill side of the track.
j) In case of cabins with boarding and de-boarding from the same side of the cabin, the width of the station embarking platforms shall be at least 1 m wider than that of the vehicle body. If boarding and de-boarding is done from different sides of the cabin then the boarding side platform should be at least 1.5 m wide and the de-boarding side should be at least 750 mm wide.
k) The platform next to the cabin terminal location may be used by waiting passengers provided there are chains or gates operated by attendants at the platform edge to prevent passengers stepping off the edge of the platform. If so desired then automatic synchronized gates may be provided that open and close in sync with the cabin gates. No attendants are mandatory if automatic gates are provided. If none of the above are provided then waiting passengers should be held at a different location and allowed on to the platform only after the cabin has arrived and stopped.

4.7.5 The maximum permitted number of persons and the live load in kg to be carried by each vehicle shall be conspicuously displayed in all vehicles.

4.7.6 The passenger carrying capacity shall be calculated as follows:

a) For seated passengers:

Seat width:	0.4 m
Seating pitch:	0.7 m

b) For standing passengers:

Floor area of 0.25 m^2 for each standing passenger.

4.7.7 Vehicles that allow standing passengers shall be provided with adequate handrails etc. Unattended vehicles shall be equipped with a device which indicates that there is an overload. This should be interlocked with the starting mechanism.

4.7.8 All metallic vehicle parts shall be equipotentially bonded and effectively earthed.

4.7.9 If the vehicle has two compartments, they shall be connected by a double fastening, each having a minimum factor of safety of 6. Each compartment shall also be provided with an emergency track brake of its own.

4.7.10 The direction of travel and speed may be controlled from the vehicle. The instructions to proceed shall be made subordinate to instructions to stop and to instructions to reduce speed.

4.7.11 Vehicles shall be fitted with interior lighting and headlamps, and shall be earthed. Flooring shall be of non-slippery material.

4.7.12 Vehicles shall be numbered or colored for identification.

4.7.13 All switches, controllers, meters and lamps on the control console in the vehicles shall be clearly labelled, in both Local and English languages as to their functions.

4.7.14 The level of each access door with respect to the corresponding landing elevation on the platform shall be designed to facilitate the passage of elderly people with minimal hindrance.

4.7.15 For all components constituting the vehicles, the factor of safety (FOS) shall be at least 2 measured against the tensile yield strength under both static and dynamic conditions.

4.8 Track

4.8.1 The track, including rails, switches, sleepers, foundation and any bridges, shall be so designed, constructed and maintained to absorb any forces from the vehicles under the most adverse conditions of loading and during emergency braking, without undue deflection or permanent deformation.

4.8.2 After every application of the vehicle track brakes, the track shall be inspected by experienced technical personnel in details, in particular the 50 m length on either side of the point of application of the track brakes.

4.8.3 The track shall be kept clear at all times of debris, soil and rocks, so allowing free passage of the vehicles and causing no impediment to the natural drainage along the track.

4.8.4 The track shall be laid in the straightest possible manner and with the most even angle of inclination possible.

4.8.5 Lateral curve radii shall be as large as possible. They shall be at least 6 x V^2 in m, where V is the speed of vehicle in m/s, and shall not be less than 100 m.

4.8.6 Means shall be provided to keep the haulage rope in touch with the rollers at all times even where the track has a concave profile.

4.8.7 The track shall be protected from unauthorized access as far as practicable.

4.8.8 A walkway shall be provided along the whole length of the track. Where this is not practical, proper means of emergency evacuation from the vehicles shall always be provided.

4.8.9 At the ends of the track, inspection pits shall preferably be provided in which work can be carried out by maintenance staff in an upright position. In order to protect the safety of staff working in the pit, the following safety installation shall be provided:

a) An emergency stop switch inside the pit to stop the vehicle through the activation of the emergency brake or the service brake; or
b) A master switch within the control panel of the vehicle which will be locked off during the maintenance work and the key is to be kept by staff working at the pit.

4.9 End Buffers

4.9.1 The distance between the buffer and the normal stopping position of the vehicle shall be at least equal to the braking distance with the application of the emergency brake. When vehicle approaching to the end switches with a permissible speed as per **4.9.2**.

4.9.2 The capacity of the buffers shall be designed to be capable of absorbing the kinetic energy of the vehicle under loaded condition. The permissible speed of 0.7 m/s or less, when vehicle approaches to the end switches as mentioned in **4.17.12**, shall be used for calculating the kinetic energy as well as the braking distance mentioned in **4.9.1**

4.10 Stations

4.10.1 According to the climate of the area where the funiculars are situated, suitable shelters for passengers and personnel shall be provided, as agreed by the buyer and the manufacturer. Such shelters shall conform to the local statutory regulations.

4.10.2 The station machinery, such as mechanical parts of the driving gear, electrical equipment, ropes and vehicles shall not be a source of danger to the passengers and ropeway personnel. The passenger entrance shall not cross the path of the travel of the vehicles without ensuring proper safety to avoid any possible accident to the passengers.

4.10.3 The layout and disposition of the stations shall be such that the access and exit points are clear, even at times of maximum passenger flow. The circulation of passengers is, as far as possible, unhindered. Sufficient covered space shall be provided, under average passenger flow conditions, for waiting passengers

4.10.4 The whole of the driving gear and deflection devices shall be protected against bad weather. Moreover, care shall be taken to prevent the entrance to the machine room of unauthorized persons to avoid any possible accident to them.

4.10.5 Funicular operator shall be located where best possible view of the route is possible. Controls and communicating devices shall be within operator's reach.

4.10.5.1 The control panel shall be provided with the following:

a) Speed indicator; and
b) Fault indicator.

4.10.6 Fire hazard shall be reduced as far as possible. Fire extinguishers as per local area regulations guaranteed to function effectively shall be kept ready in case of need and installed in places which are readily accessible.

4.10.7 The building structures and facilities shall be constructed with reference to the relevant BIS Buildings code IS 875. The design of the terminal buildings shall take account of all the imposed forces, including rope tensions and an earthquake loading as indicated in 4.5.2. Lightning protection shall be in accordance with IS 62305 (Part 1).

4.10.8 The width of the station embarking/ disembarking platforms in different conditions are given in **4.7.4**.

4.10.9 The clearance between the edge of the platform and the door opening of the vehicle shall preferably not exceed 50 mm.

4.10.10 Passengers shall not have access to any area housing machinery or operational equipment and shall be given access only to the boarding and alighting areas.

4.10.11 Notices to the passengers shall be posted in conspicuous positions and shall be written in both Local & English languages. Signages are allowed. Entry and exit points in a station shall be clearly illustrated.

4.10.12 Adequate lighting either natural or artificial, shall be provided for public areas, machine room, control room and maintenance areas. Emergency lighting shall be available from a secure supply.

4.11 Structures and Support Girders/Bridges

4.11.1 In designing, the following stress values shall be taken into account:

a) The weight of the trestle and the pressure exerted by the ropes;
b) The whole of the stresses due to friction met with during the motion of the moving ropes;
c) Weight of the vehicles travelling with maximum load (considered conventionally static load);
d) Wind load or snow load; and
e) Load imposed by communication cable, if provided.

4.11.2 The metal parts of the structures shall have a safety factor defined as the ratio of the ultimate strength of the metal to stress in the metal under the most unfavorable conditions of not less than 3.0 when the installation is in service.

4.11.3 The elastic deformation of the structures, in particular those due to torsion which happens during normal conditions of operation, shall not be such as to endanger the safety of the guides and the stability of the ropes.

4.11.4 The number of trestles, their position, their height and their construction are determined by the requirements of the route and the layout.

4.11.5 In case the structures have metallic framework, the thickness of the open profile shape shall not be less than 5 mm while in the case of closed profile; it shall not be less than 2.5 mm. The interior of the latter shall be adequately protected against corrosion.

4.12 Foundations

4.12.1 The foundations shall have a factor of safety of1.5 in respect of shifting and over turning. Such factor of safety is to be calculated on the basis of a conventional assumption that these foundations are free, that is, there is no lateral movement of the earth.

4.12.2 All foundations shall be in accordance with IS 4091. For the structural safety against sliding, overturning and for the footings at different levels provisions laid down in IS 1904 shall apply. The depth of footings and other provisions shall conform to the provisions laid down in the relevant Indian Standards depending on the type of foundation [*see* IS 1904, IS 1080, IS 2950, IS 11089, IS 9456, IS 2911 (Part 1/ Sec 1), IS 2911 (Part 1/Sec 2), IS 2911 (Part 1/Sec 3), IS 2911 (Part 1/Sec 4) and IS 2911 (Part 3)].

4.13 Sheaves, Drums and Rollers

4.13.1 The diameter of deflection pulleys of stranded stretch wire rope shall be not less than 40 times that of the wire rope nominal diameter and 600 time that of the wire in the outer layer of the wire rope. These pulleys shall be provided with linings in leather, wood or any other relatively soft material.

4.13.2 The diameter of the driving sheaves/drum shall be not less than 80 times that of the hauling rope nominal diameter and 800 times that of the wires of the wire rope.

4.13.3 The maximum load exerted by the hauling rope on the rollers shall not be more than 2 kN per roller having the groove without soft material lining. When the groove has lining, the allowable load may be higher (for instance, as regards rubber of good quality, such load may reach the value of 4 x d x D, expressed in N, when d is the diameter of the rope and D the diameter of the roller, both are expressed in cm).

4.13.4 The diameter of the haulage fastening drum shall be not less than 22 times that of the hauling rope nominal diameter.

4.13.5 Under normal operating conditions (normal service, stopping; emergency stop with drive motor; emergency stop with service brake with normal functioning brakes) – except when the carriers are actually passing – lifting the haul rope from its rollers is not permitted.

4.13.6 Safety devices shall be provided which automatically trigger the stoppage of the installation if the haul rope is in an incorrect position in relation to the line rollers.

4.13.7 The distance between successive rollers shall be designed such that even when it oscillates, the haulage rope shall not come into contact with the track bed or the sleepers on the track.

4.14 Wire Ropes

4.14.1 As far as possible, one single haulage rope in single piece with non-rotating construction shall be used.

4.14.2 Before the wire ropes are put into service, they shall be checked by a suitable non-destructive method, like magneto inductive test, to ensure that the requirements in **4.14.8** are fully met. Such tests shall be carried out periodically by any Government approved lab or test house accredited by NABL/statutory regulations.

4.14.3 Lubricants incorporated in the wire rope during manufacturing shall not exert any corrosive action on the material of the rope. Lubrication of the rope during service shall be done according to the specific requirements.

4.14.4 Care shall be taken to avoid any twisting or kinking of the rope during un-reeling the rope or in service.

4.14.5 Stranded wire ropes of fiber or solid plastic core are suitable.

4.14.6 The minimum breaking strength of the haulage rope shall be at least 8 times the maximum tensile load met with in service**.** In the calculation of the maximum tensile load the most unfavorable combination of circumstances shall be taken into account. Loads due to atmospheric influence and due to wind may be neglected.

4.14.6 Maximum 'Factor of Safety*'* (FOS) should not exceed 15.

4.14.7 Testing and Acceptance of Ropes shall conform to the relevant Indian Standards.

4.14.8 Generally a rope should be withdrawn from service when it is considered that:

a) The loss of strength in the rope due to wear or corrosion or both is approaching one-sixth of the original strength;
b) The loss of strength in the rope due to fatigue, surface embrittlement or cracked and broken wires of any kind is approaching one-tenth of the original strength;
c) The outer wires have lost about one-third of their depth as result of any kind of deterioration;
d) The outer wires are becoming loose and displaced for any reason;
e) The rope has become kinked, distorted or damaged and the damaged piece cannot be removed ;
f) Examination of the rope leaves any doubt as to its safety for reason whatsoever; and
g) Number of wires rupture in the rope exceeds the limit specified in **8.1.6** of IS 3973.

4.14.9 For telephone and signaling cables the safety factor shall be at least 3.3 times the maximum designed axial stress. Cables used for telephone and signaling purposes shall not come into contact with the haulage ropes under the worst possible operating conditions.

4.14.10 Splicing and Rope Terminations:

a) Splicing of the haulage rope is not permitted;
b) The haulage rope fastening to the vehicle shall be easily accessible for inspection and adjustment;
c) Reel-type fastening to vehicle shall have a safety factor of 4 as measured against the greatest traction force in the rope. Other types of fastening shall be designed for the breaking load of the rope;
d) The fixing of the ropes onto the haulage drum shall be carried out using a system of blocking with wedges, or using at least two clamps or any other system of equivalent design from the safety point of view. These attachments shall be easily accessible for inspection and tightening. If the size of the drum permits, the rope shall first pass through a hole in the drum barrel or flange and be secured on the inside of the barrel or on the outside of the flange. The termination shall be able to resist at least 80% of the breaking load of the rope;
e) If end sockets are to be used, they must be fitted with care. For this purpose only firms who specialize in this technique and can prove their experience, both as regards the making of the sockets and the choice of correct materials shall be employed, unless the operating company has its own qualified personnel who have proper experience in this work. During service the rope ends shall be easily accessible for inspection;
f) The sockets shall be fitted with a white metal that may be applied at a temperature below that of any critical temperature which will alter the metallurgical or mechanical properties of the wire;
g) The wires in the cap shall be spread to evenly distribute the load and arranged that no bending moment is applied to the rope as it leaves the socket;
h) On installation of an end socket a transverse reference mark shall be made so that any displacement can be readily detected visually; and
j) The end socket shall have strength at least that of the parent rope. It shall be protected from the ingress of water or any other substance that may be corrosive or affect the integrity of the fixing.

4.15 Drive

4.15.1 The main drive shall be able to operate under any loading condition from rest to any selected speed within the design range. As far as practicable the speed selected shall be suitably controlled and be constant with variation limited to ±5 percent of the selected value.

4.15.2 The starting of the motor shall be smooth and without jerking regardless of the load. Starting acceleration shall be adjusted according to the track characteristics, and passenger comfort considerations.

4.15.3 It shall be possible for the motor to drive the rope at 0.3 m/s or at such a speed so as to allow the entire length of the rope to be inspected.

4.15.4 For the purpose of calculating the necessary drive output of the motor and the rope tension, the weight of a person shall be taken as specified at **4.7.1**.

4.15.5 The running resistance of lined rollers shall be taken as at least 3 percent and of unlined rollers as at least 1percent of the load exerted on each roller when the rollers are provided with anti-friction bearings.

4.15.6 The resistance of rope sheaves shall be taken into account in calculating the necessary drive output.

4.15.7 The driving gear shall be provided with an emergency system fed by auxiliary power which shall be used only for rescue/evacuation operation.

4.15.8 In the event of power failure, passenger transportation shall be forbidden unless hundred percent power backup is provided.

4.15.9 In the case of downward load, the driver itself shall exert a continuous braking action.

4.15.10 Travel with the main motor shall be stopped automatically when any brake is on or if any safety device operates.

4.15.11 *Rope Adhesion on the Driving Sheave*

The following Co-efficient of friction (μ) shall be considered for different materials:

Rubber-lined rollers	3.0 percent

Plastic-lined rollers	2.0 percent
Sheaves with roller bearings	0.3 percent
Sheaves with journal bearings	1.0 percent
Steel wheels on carriers without eccentric haul rope connection	1.0 percent
Steel wheels on carriers for funicular railways in the case of horizontal bends or eccentric haul rope connection	2.0 percent
Pneumatic tyres on carriers for funicular railways on concrete or steel girders without eccentric haul rope connection	1.5 percent
Pneumatic tyres on carriers for funicular railways in the case of horizontal bends or eccentric haul rope connection	2.5 percent

4.15.12 The contact angle of the rope on the driving sheave shall be such as to ensure that in the most unfavorable combination of circumstances the required power is transmitted to the rope.

4.16 Brakes

4.16.1 Two different friction brakes with independent source of power shall be used in case of electric motor drive to cause both the normal stopping and emergency one.

a) One of these brakes is called 'Service Brake' and it can be fitted on gearbox input shaft or on the bull-wheel rim.

With an electrical main drive motor, the service brake shall operate automatically as soon as:

- i) The speed controller is brought into neutral position, if speed controller is installed;
- ii) The electrical braking is almost completed;
- iii) The supply power is lost, interrupted or the voltage falls below a permissible level, or in the case of three-phase circuits, the supply fails in any one phase;
- iv) The power demand rises above a permissible level;
- v) The maximum permissible running speed is exceeded by 10 percent; and
- vi) Any of the safety devices listed in **4.17** operates.

b) The other is 'Emergency Brake' and should be fitted directly on bull wheel rim. Each of such brakes shall be able to ensure the safe stopping of the installation's motion under most unfavorable conditions of loading. In any case, the nominal average deceleration shall not exceed 0.5 m/s^2.

c) The emergency brake, without deceleration control, shall be set to achieve a retardation of at least 0.5 m/s^2 in the most adverse line conditions for full downhill load/empty uphill load and a maximum of 1.5m/s^2 in the most adverse line conditions for full uphill load/empty downhill load. In all cases, the emergency brake, when applied at any point during the normal deceleration phase during entry to station, must be capable of stopping the vehicles before the buffers at the terminal stations, irrespective of the load.

d) The emergency brake shall be able to be brought into action by hand at the control console either mechanically or electrically. Emergency stop switch or push button to stop the vehicle shall be provided at the following locations:

- i) control console in the control room;
- ii) on the platforms;
- iii) control panel in the vehicle;
- iv) in the machine room;
- v) in the passenger compartments if the vehicle is not attended; and
- vi) in the vehicle inspection pit.

e) The emergency brake shall come into operation automatically under the following conditions:

- i) when the maximum permissible running speed is exceeded by 15-20 percent;
- ii) when the vehicle overshoots its normal stopping position at the driving station;
- iii) when the service brake fails; or
- iv) when the pressure in the hydraulic or pneumatic circuit for holding open the brake drops below the specified level.

4.16.1.1 When the vehicle is to stop in a normal manner, the deceleration shall be achieved by means of an electrical brake. As far as possible, a constant deceleration sufficient to slow down the vehicle. In this respect, a deceleration value of at least 0.2 m/s^2

shall be achieved. The deceleration shall be monitored by the deceleration monitoring circuit.

4.16.1.2 For both the brakes, springs shall induce its braking effort and its operation shall be carried out in a manner that its regular working can be automatically and constantly checked. It shall also be capable of being released manually.

4.16.1.3 In the event of overspeed, the emergency brake shall operate automatically in both directions of travel and shall be fail-safe, i.e. not dependent upon the power derived from mains supply or batteries. The braking force of the emergency brakes shall be produced by compression spring. The overspeed governor shall have an accuracy of ±5 percent. Automatic resetting of governor shall not be allowed.

4.16.1.4 When the emergency brake is applied, the electrical supply to the drive motor shall be tripped-off. When the emergency brake is controlled (held open) hydraulically or pneumatically, the hydraulic or air pressure shall be completely released immediately. To avoid excessive deceleration, the operation of the emergency brake may be delayed.

4.16.1.5 The braking force of all brakes shall be easily adjustable. When the brakes are held open hydraulically or pneumatically, the corresponding pressure shall be capable of being monitored.

4.16.1.6 The components of the brakes shall be designed with a minimum factor of safety of 2.0 as measured against the tensile yield strength.

4.16.1.7 Due consideration shall be given to the temperature rises when calculating the dimensions and efficiency of the brakes.

4.17 Safety Devices and Control Circuit

4.17.1 The control room shall be located in the driving terminal and shall be so orientated as to afford the best possible view of the line. The approaching of vehicle and the boarding and alighting of passengers shall be clearly visible in front of the control console inside the control room. However, the use of CCTV will be accepted as an alternative.

4.17.2 All control and safety circuits/devices shall be monitored and annunciated by means of indicator lights or audible alarms. All instruments and devices required for monitoring of the operation shall be housed and made easily accessible in the control room.

4.17.3 All instruments and lamps shall be clearly labelled, as to their functions, in both English and local language. Signal lamps shall be clearly visible when lit. When necessary, the signal lamp can be accompanied by audible signal.

4.17.4 To safeguard the failure of the control system at the vehicles, a manual control system shall be provided at the control room which makes it possible to run the vehicle at a maximum speed of 2m/s.

4.17.5 Starting up of the vehicle shall only be possible when:

a) The corresponding start command has been initiated from both vehicles;
b) “door closed” signal(s) from both vehicles; and
c) The corresponding “start” command from the control console at the control room”

4.17.6 Any intended reversal of the direction of travel shall be possible only after the vehicles are brought to a complete standstill/stop.

4.17.7 Vehicle position indicator to show the vehicle position in meter and with the indication derived from the signal of a counting device at a deflection sheave of the haulage rope or main haulage drum (in case of winch drive) shall be provided. The position of all stations and crossing points shall also be shown. When two vehicle position indicators are provided at different locations, their indication shall be synchronized. The vehicle position indicator shall automatically correct the position indication in such a way that the starting positions are indicated when the vehicles are in the termini.

4.17.8 In particular, the followings shall be monitored with indication displayed at the control room:

a) The status of drive, i.e. By main drive or auxiliary drive(in case provided). Interlocks shall be provided that both drives shall not operate simultaneously;
b) The position of the brakes;
c) The condition of wear of the brake shoes unless regular maintenance check has been properly implemented to avoid wearing of the brake shoes exceeding its replacement value.

4.17.9 The Funicular shall be provided with end switches and buffers. The end switches shall bring about automatic stopping and impose change of direction of travel.

4.17.10 The speed of the vehicle shall be reduced gradually to the comfort of the passengers before entry to the terminal station. The reduction in speed shall be effected by an entry deceleration circuit.

4.17.11 For Funicular which may be remotely controlled, two independent arrival monitoring systems shall be provided.

4.17.12 The arrival monitor shall activate the safety circuit to slow down or stop the vehicle if the speed of the vehicle has not been reduced to the permissible 0.7 m/s or less on its approach to the end switches.

4.17.13 Upon actuation of the arrival monitoring circuit, the vehicle must be brought to a complete halt in front of the buffers by the emergency brake.

4.17.14 The speed sensing device for at least one of the arrival monitors shall be driven directly by the driving drum or deflection sheave. The output signal from the speed sensing device shall be continuously monitored.

4.17.15 Additional safety device shall be provided after the end switches which will actuate the emergency brake.

4.17.16 For manually controlled railways, the approach of the vehicle to the terminus shall be indicated by an audible signal in the control room.

4.17.17 Automatic stopping must occur as soon as any breakdown occurs in the safety or control circuits. No re-start shall be possible until the fault is cleared. The operation of any safety circuit shall be clearly annunciated in the control room giving information as to the type and location of the fault.

4.17.18 Emergency stop buttons provided at locations under l4.16.1 (b) shall be distinguished by color and label.

4.18 Bridging Circuits

a) If a fault is occasioned by a breakdown or malfunction of the control circuitry it may be permissible, under certain circumstances, to by-pass that part of the circuit component with a bridging circuit. Any such devices should be correctly engineered and their functions clearly described in the design documentation. Their use, however, will be restricted to responsible staff and under no circumstances must their use prejudice safety;
b) The bridging circuit shall only be made possible by a key switch; and
c) The travelling speed shall not exceed 2m/s during bridging of the control circuitry.

4.19 Remote Monitoring System

4.19.1 Remote Monitoring System shall be provided to monitor whether the haulage rope is guided along the proper positions and check the integrity of signal cables.

4.19.2 If the travelling speed is greater than 3 m/s, the haulage rope shall be monitored by a monitoring circuit.

4.19.3 Trackside or overhead signal cables which carry information relating to the railway safety shall be monitored by a monitoring circuit.

4.19.4 Stoppage of the Funicular shall be initiated whenever the monitoring circuits are interrupted, short circuited with other monitoring circuit, or earthed.

4.19.5 Voltages up to 50 volts are allowed in the monitoring circuits between circuit and earth, and between circuit and circuit.

4.19.6 The monitoring circuits shall have an impedance of not less than 20,000 ohms at a minimum testing voltage of 500 volts.

4.20 Communication

4.20.1 For manually controlled Funicular with relatively straight and short track, one set of signaling equipment shall be sufficient.

4.20.2 A communication system between the driver in the driver cabin of the vehicle and the duty technician in the control room shall be provided. The communication or signaling equipment shall continue to work in the event of mains supply failure, application of any brakes, tripping of end switches or actuation of safety circuits.

4.20.3 If permanently applied current collectors are used for passing signals and instructions, those contact points or shoes shall be checked regularly for interruptions. They should work on a “fail safe” system so that any discontinuity prevents the system from working.

4.20.4 The vehicle shall be provided with a public address system that is audible at any point inside the vehicle. Annunciation informing passengers on action to be taken in the event of the vehicle coming to a halt between normal stopping places shall be given through the system. For vehicle without attendant, an intercommunication system between the passenger and the control room shall be provided.

4.21 Evacuation Pathway

In the case of funicular railways, if passengers are evacuated by a pathway alongside the track, this pathway shall have a width of at least 0.6 m. If there is a risk of lateral fall, the following shall be installed:

a) Handrail on the side opposite the axis of the track, if the fall height is at least 1.0 m;
b) Railing along the edge, if the fall height is over 1.0 m; and
c) If there are steps, provision shall be made for a handrail and rest areas.

Measures shall be provided to ensure safe departure from the carriers, also in the area of passing loops and crossing points.

4.22 Operating Conditions

The automatic operation of funicular railways without the immediate presence of personnel at the installation may take place subject to the following conditions.

4.22.1 *Operation Monitoring*

It shall be possible to reach the installation within 30 min in the event of a fault in order to take the appropriate action.

Closed circuit TV monitoring of the platform areas shall be provided with a monitor at the monitoring position.

4.22.2 *Fencing off the line*

Those parts of the line of the funicular railway which are accessible by unauthorized persons shall be fenced off.

The fencing shall be at least 1.8 m high. In rural environments, this may be reduced to 1.2 m.

4.22.3 *Access to the line*

Any doors in the fencing required in accordance with (b) shall be fitted with safety devices. If the doors are opened, the installation shall automatically be brought to a stop and further operation shall not be possible. The further operation of the installation may be permitted only after the line has been inspected and authorization has been given by the personnel.

When a door is also specified for use for the evacuation of passengers, it shall be possible to open it from the inside.

4.22.4 *Evacuation*

In the event of a stoppage, it shall be possible for passengers to evacuate from the carriers without danger by complying with instructions displayed in the carrier or communicated by the monitoring station. An evacuation pathway conforming to **4.21** shall be provided. It shall be possible to open the doors and emergency exits from the inside.

The passengers shall have at their disposal in the carrier an alarm button allowing them to notify the monitoring station.

If it is possible for operating personnel to reach the carriers within a short time after a stoppage, other evacuation methods may also be used.

4.22.5 *Access to carriers*

During operation, it shall not be possible (except for maintenance work) to open a sliding door (or any of its leaves) unless a carrier is at rest in the opening area of the sliding door.

If a sliding door (or one of its leaves) is open, it shall not be possible to start up the installation. If the installation is in motion and a sliding door (or one of its leaves) is opened, the installation shall be stopped automatically and an automatic restart shall not be possible. The further operation of the installation may be permitted only after the line has been inspected and authorization has been given by the personnel.

4.23 Safety Requirements

4.23.1 The cabins must be provided with door lock, which cannot be opened by the passengers.

4.23.2 Two separate brakes shall be provided in the drive of ropeway system. One brake is provided on drive sheave. This will act as emergency brake. A second brake is provided on high speed shaft which will act as service brake. The brakes must come in operation automatically when:

a) Normal stop/emergency stop push button is pressed;
b) The ropeway speed exceeds by 5 percent of the set speed;
c) The tripping of drive motor due to actuation of line and station security devices; and
d) In case of power failure.

4.23.3 The vehicle shall be provided with an automatic track brake, which acts on the rail in the case of breaking or loss or tension in haulage rope. This brake shall be capable of manual operation by the operator also. It should also be capable of being disengaged by the operator after it has functioned.

4.23.4 Arrangement should be made so that the brakes can be released during emergency running of the system.

4.23.5 Standby prime mover is required to run ropeway at slow speed, to rescue passengers from line in case of failure of main motor or power failure or DG set failure.

4.23.6 Emergency push buttons must be provided at all stations to stop the ropeway.

4.23.7 Anemometer at an appropriate location shall be installed to monitor the wind speed and in the event of crossing the pre-determined wind speed; it will trip the main drive motor.

4.23.8 A speed control device which automatically stops the vehicle when the speed of the vehicle approaching the station has not been suitably reduced shall be provided.

4.23.9 Fire hazard shall be reduced as far as possible. Fire extinguishers as per local area regulations guaranteed to function effectively shall be kept ready in case of need and installed in places which are readily accessible.

4.23.10 The entire Funicular system shall be provided with suitable protection against lightning.

4.24 Annual Inspection

The annual inspection, which shall be performed by an approved surveyor by the Owner/Client/ Department and shall cover at least the following items: -

a) The normal operating data and general condition of the installation;
b) Checking of main gearbox for lubrication and measurement of backlash;
c) Checking of main haulage drum shaft and output shaft for clearance;
d) Checking of haulage drum and deflection sheaves for surface cracks or defects;
e) Checking of overload protection for motors and generator;
f) Checking of hydraulic circuit for correct pressure settings and testing of their function;
g) Checking and testing of safety devices installed at terminal including the vehicle position indicators and over-travel limit switches;
h) Checking and testing of electrical safety circuit;
j) Checking of rope monitoring circuit;
k) Checking of arrival monitors and the associated control circuit;
m) Checking of overspeed protection at 10 percent;
n) Checking of electrical installation at the intermediate stations and along the route;
p) Checking of lightning protection at terminals;
q) Testing of service brake and emergency brake in control room;
r) Testing of service brake and emergency brake upon activation in vehicle with one vehicle fully loaded, another empty.
s) Travelling at rated speed, in both directions of travel. Record the braking distance and time;
t) Checking and testing of the track brakes installed in both vehicles with the tested vehicle fully loaded, another empty, travelling at reduced speed at the steepest slope of the track. Record the braking distance and time for each vehicle;
u) Checking of haulage ropes by taking measurement of the diameter of some sections of the rope, visual inspection of the condition of the rope, and taking the magnetograph reading of the rope;
v) Checking of vehicle for corrosion, deformation or damages;
    1) Checking of tightness of bolts and rivets in vehicle;
    2) Checking the condition of the track and its structure such as bridges, for looseness of bolts, corrosion, and deformation;
    3) Checking of rollers along the track for wear and misalignment;
    4) Checking the stability of slope, embankment and protective walls along the track;
    5) Checking of force bearing components in stations and machine room; and
w) Recommendations to improve the safety standard of the installation.

ANNEX A

(*Clause* 2)

IS No.	*Title*
IS 802 : Part 1 : Sec 1 : 2015	Use of structural steel in overhead transmission line towers — Code of practice — Part 1 materials, loads and design strengths : Sec 1 materials and loads (*fourth revision*)
IS 802 : Part 1 : Sec 2 : 2016	Use of structural steel in overhead transmission line towers — Code of practice — Part 1 material, loads and permissible stresses : Sec 2 permissible stresses (*fourth revision*)
IS 875 (Part 3) : 2015	Design Loads (Other than Earthquake) for Buildings and Structures — Code of Practice — Part 3 Wind Loads (*third revision*)
IS 875 (Part 4) : 2021	Code of practice for design loads (Other Than Earthquake) for buildings and structures — Part 4 Snow loads (*second revision*)
IS 875 (Part 5) : 1987	Code of practice for design loads (Other Than Earthquake) for buildings and structures — Part 5 Special loads and load combinations (*second revision*)
1080 : 1985	Code of practice for design and construction of shallow foundations in soils (other than raft, ring and shell)
10891 (Part 1) : 2001	Steel Wire Ropes for Aerial Ropeways- Specification — Part 1 Haulage Ropes (*first revision*)
1804 : 2004	Steel Wire Ropes — Fiber Main Cores — Specification
1893 : 1984	Criteria for earthquake resistant design of structures
1904 : 2021	Code of practice for design and construction of foundations in soils —General requirements
IS 2911 : Part 1 : Sec 1 : 2010	Design and construction of pile foundations - Code of practice : Part 1 concrete piles : Sec 1 driven cast in — Situ concrete piles (Second Revision)
IS 2911 : Part 1 : Sec 2 : 2010	Design and construction of pile foundations — Code of practice : Part 1 concrete piles : Sec 2 bored cast in — Situ concrete piles (Second Revision)
IS 2911 : Part 1 : Sec 3 : 2010	Design And Construction Of Pile — Foundations â€” Code Of Practice Part 1 Concrete Piles — Section 3 Driven Precast Concrete Piles
IS 2911 : Part 1 : Sec 4 : 2010	Design and construction of pile foundations - Code of practice : Part 1 concrete piles : Sec 4 precast concrete piles in prebored holes (First Revision)
2911 (Part 3) : 2021	Code of practice for design and construction of pile foundations under — reamed piles
2950 (Part 1) : 1981	Code of practice for design and construction of raft foundations
3973 : 1984	Code of practice for the selection, installation and maintenance of wire ropes
4091 : 1979	Code of Practice for Design and construction of foundation for transmission towers and poles
5230 : 2017	Code of Practice for To and Fro (Jig Back) Movement Bi-Cable Ropeways

IS No.	*Title*
7649 : 1975	Glossary of terms used in connection with aerial ropeways and cableways
9456 : 1980	Code of practice for design and construction of conical and hyperbolic paraboloid types of shell foundations
11089 : 1984	Code of practice for design and construction of ring foundation
14329 : 1995	Malleable iron castings
62305 (Part 1) : 2010	Protection against lightning — Part 1 General Principles

ANNEX B

(*Foreword*)

COMMITTEE COMPOSITION

Continuous Bulk Conveying, Elevating, Hoisting Aerial Ropeways and Related Equipment Sectional Committee, MED 06

Organization(s)	*Representative(s)*
RITES Limited, Gurugram	Shri Sandeep Mehra (***Chairman***)
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Conveyor and Ropeway Services Private Limited, Kolkata	Shri S. Shekhar Chkravarty Shri Kamal Kumar Bose (*Alternate*)
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Organization(s)	*Representative(s)*
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RITES Limited, Gurugram	SHRI DINESH KUMAR
Ropeway and Resorts Private Limited, Kolkata	SHRI A.K. KINRA
TRF Limited (A Tata Enterprise), Jamshedpur	SHRI N. K. SINGH SHRI SUBHASH SHARMA (*Alternate*)
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In personal capacity (*20 D, Dhakuria Station Road, Kolkata - 700031*)	SHRI RANJAN MUKHERJEE
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Member Secretary
SHRI AMAN DHANAWAT
Scientist 'B' (MED), BIS

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